Chapter 4

ALOHA and Local Area Network

Contents

- Random Access Algorithms
  - Pure ALOHA
  - Slotted ALOHA
  - Reservation ALOHA
- LOCAL Area Network
  - CSMA/CD or ETHERNET
  - Token Ring Network

Pure ALAHA

- 1971, University of Hawaii began operation of ALOHA
- Satellite was used to interconnect university computers by use of a
- Random access protocol.

Pure ALOHA Modes

- **Transmission mode:**
  - Users transmit at any time they desire,
  - Encoding transmissions with error detection code.
- **Listening mode: After Message Transmission**
  - User listens for (**ACK**) from the receiver.
  - If message collides (time overlap) receives (**NAK**)
- **Retransmission mode:**
  - When **NAK** is received, the message are simply retransmitted after a random time.
- **Timeout mode:** IF, user does not receive either **ACK** or **NAK** within a specified time, the user retransmits the message.

Successful & Total Traffic

- Total traffic arrival rate λ_t equals the acceptance rate λ plus rejection rate λ_r

$$\lambda_t = \lambda + \lambda_r$$

- If average length of packet is b bits.
- So, the average amount of successful traffic (throughput) is given by:

$$\rho = b\,\lambda$$

- Whereas the total traffic being:

$$G = b\,\lambda_t$$

Normalized Throughput and Normalized Total Traffic

- Assume channel capacity (maximum bit rate is given by *R* bps)
- So, normalized total traffic will be:

$$G_n = \frac{b\,\lambda_t}{R}$$

- Whereas, normalized throughput is:

$$\rho_n = \frac{b\,\lambda}{R}$$

Normalized Throughput and Normalized Total Traffic

- If transmission time of each packet τ :

$$\tau = \frac{b}{R} \quad i.e. \frac{b}{b/s} = s$$

- Normalized throughput becomes:

$$\rho_n = \tau \, \lambda$$

- Normalized total traffic becomes:

$$G_n = \tau \, \lambda_t$$

Poisson Process

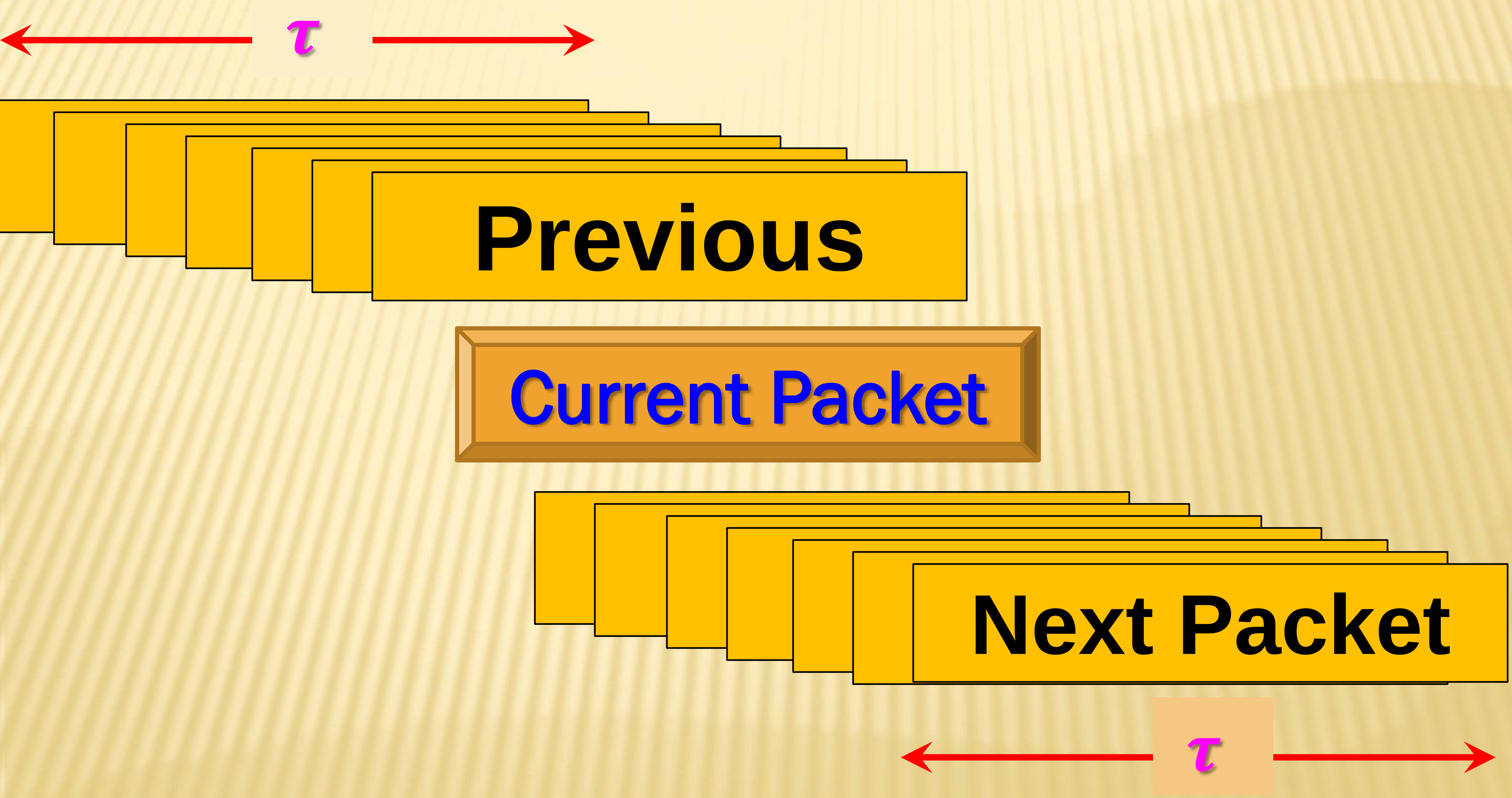
- The arrival statistics is often modeled as a Poisson process.
- So, the probability of K new messages arrive during a time interval τ sec is given as:

$$P(K) = \frac{(\lambda\tau)^{K} e^{-\lambda\tau}}{K!} \quad , \qquad K \geq 0$$

Collision Space

- If a user began message within previous τ sec, its tail end will collide with current packet.
- If another user begins a message within next τ sec, it will collide with the tail end of current packet.
- For no collision, a space of 2τ is needed.
- So, the probability of a user message is successful P_s is the probability when a 0 packets (K=0) are transmitted during a time interval 2τ (Probability of no transmission)

COLLISION INTERVAL



Probability of Success

- Putting $\tau = 2\tau$, $\lambda = \lambda_t$ and $K = 0$ gives:

$$P_s = P(K = 0) = \frac{(\lambda_t 2\tau)^0 e^{-\lambda_t 2\tau}}{0!} = e^{-2\lambda_t \tau}$$

- Also, probability that a user message is successful is given by definition as:

$$P_s = \frac{\lambda}{\lambda_t}$$

- Equating the above expressions:

$$\frac{\lambda}{\lambda_t} = e^{-2\lambda_t \tau}$$

$$\therefore \lambda = \lambda_t e^{-2\lambda_t \tau}$$

Throughput of Pure ALOHA

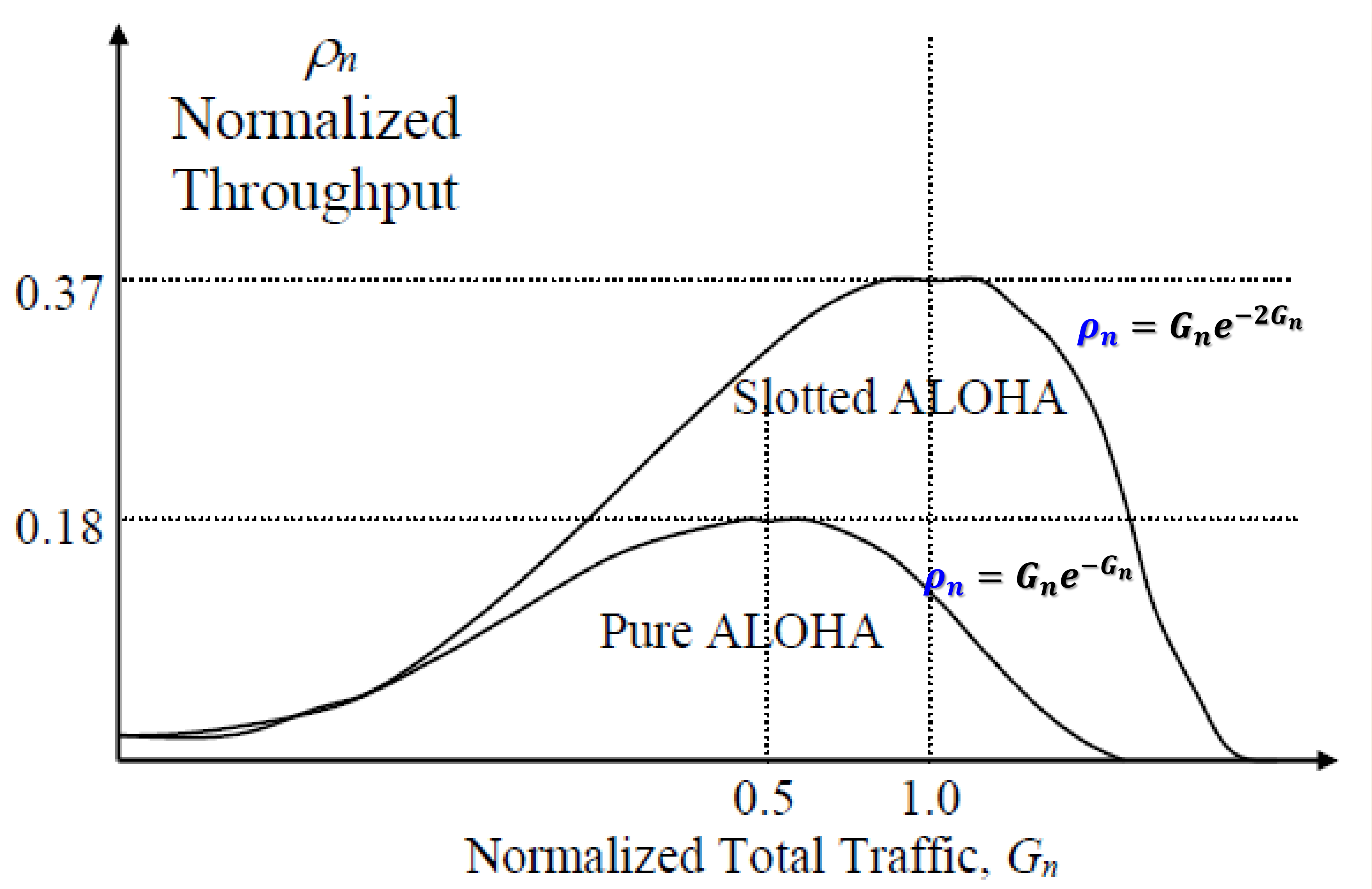
$$\therefore \lambda = \lambda_t e^{-2\lambda_t \tau}$$

$$\therefore \rho_n = \lambda\tau = \lambda_t \tau \, e^{-2\lambda_t \tau}$$

$$\therefore \rho_n = G_n e^{-2G_n}$$

- **As G_n increases r_n increases til a point where further traffic increase creates a large collision rate to cause a reduction in the throughput.**
- **Maximum throughput 0.18 at G_n= 0.5.**
- **In pure ALOHA, 18% of communication resources can be only utilized.**

Normalized Throughput



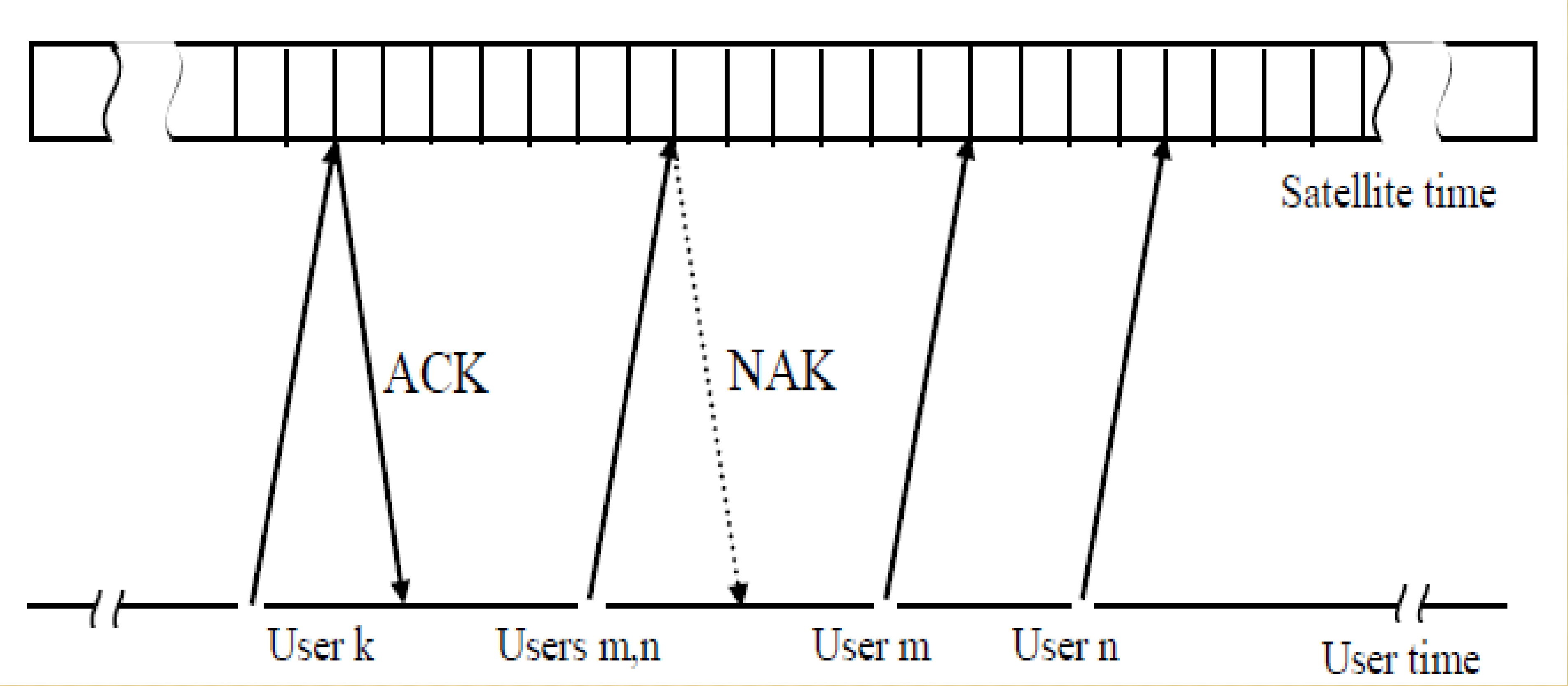
Slotted ALOHA

- **Pure ALOHA can be improved by making a small of coordination among stations.**
- **So, a sequence of synchronization pulses is broadcast to all stations. Messages are required to be sent in the slot time between synchronization pulses, and can be started only at the beginning of a time slot.**
- **This reduces rate of collisions by half, since only messages transmitted in same slot can interfere with one another. The reduction in the collision window from 2τ to τ results in:**

$$\rho_n = G_n e^{-G_n}$$

Throughput of Slotted ALOHA

- Maximum throughput is 0.37%.
- if a negative **NAK** is received, user retransmits after a random delay of integer no of slot times.



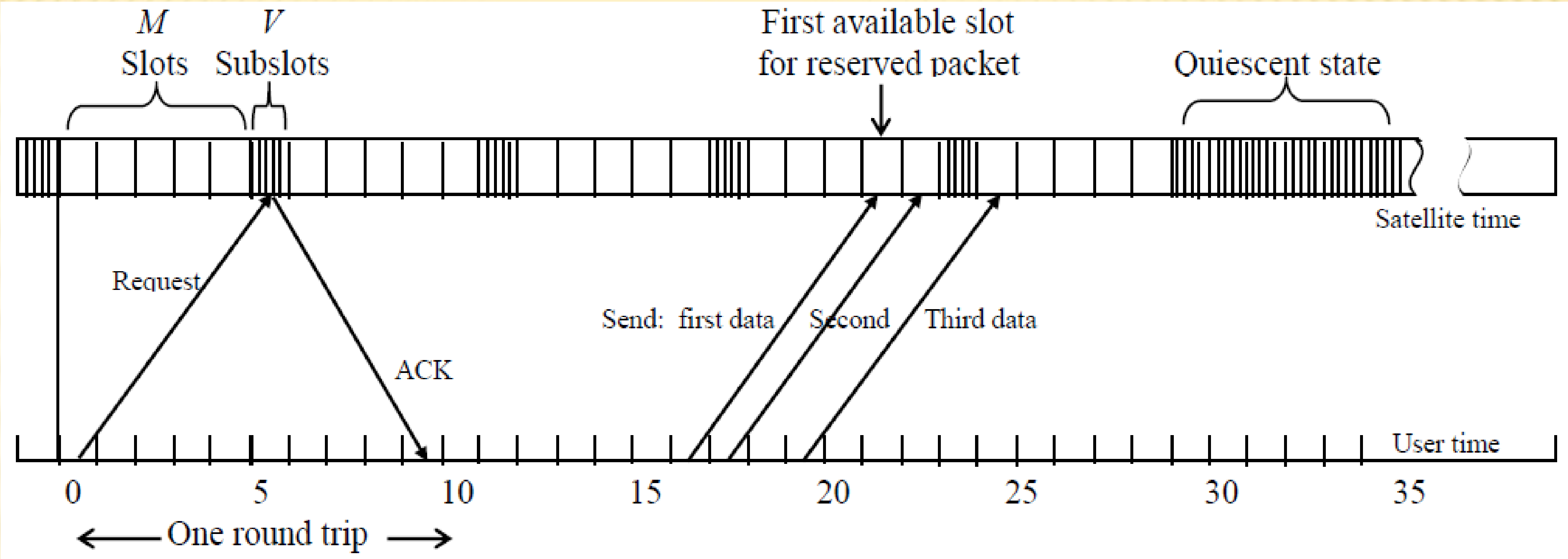
Unreserved Mode

(Quiescent State)

When no reservations taking place, system waits for requests of reservation:

- Frame time is divided into a small reservation sub-slots.
- Users use sub-slots to reserve message slots.
- After requesting, the user listens for an ACK and a slot assignment.

Reservation ALOHA



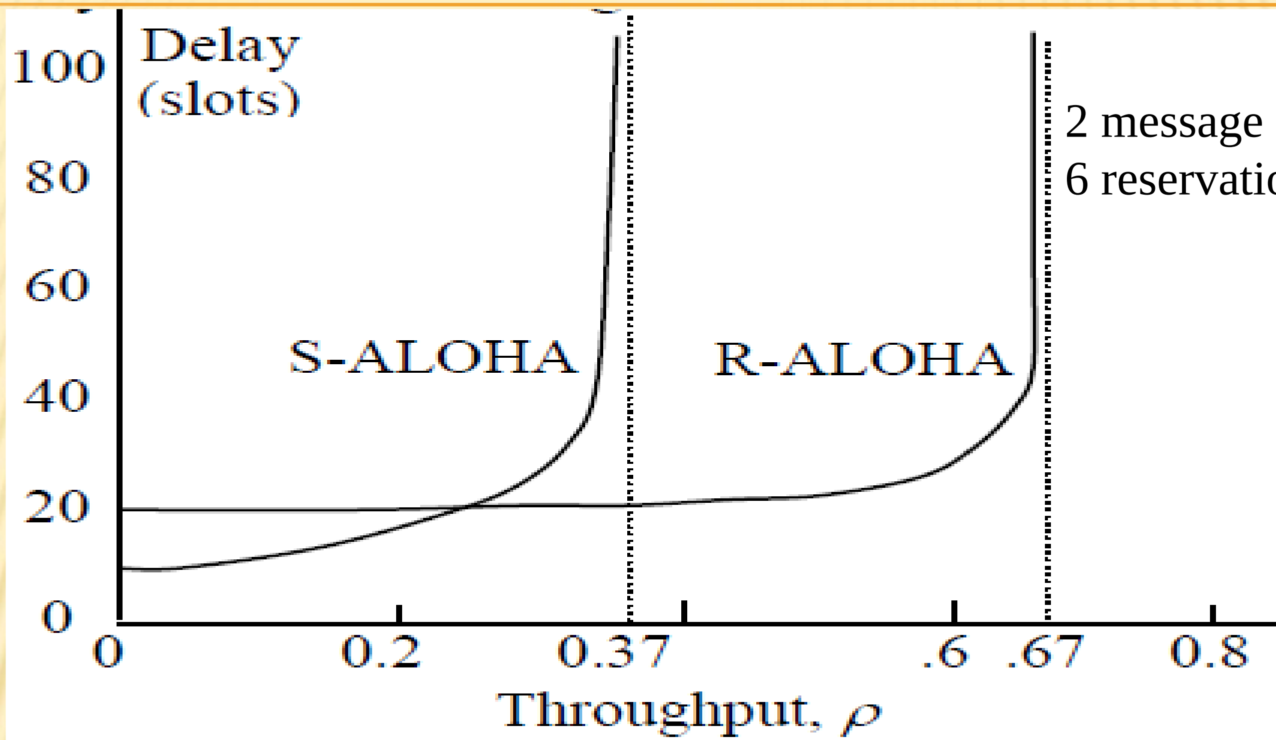
- 6 slots per frame, each can be divided into 6 sub-slots.
- In quiescent state (no reservation) time is partitioned into short 6 x 6 = 36 sub-slots.
- Once reservation is made, system is reconfigured into M=5 message slots followed by only 6 sub-slots for reservation.

Reserved Mode

Once reservation is made, the system is reconfigured as follows:

- The time frame is divided into $M+1$ slots.
  - First M slots are used for message transmissions.
  - Last slot is subdivided into sub-slots to be used for reservation/requests.
- Users sent message packets only in their assigned portions of the M slots.

Slotted and Reservation



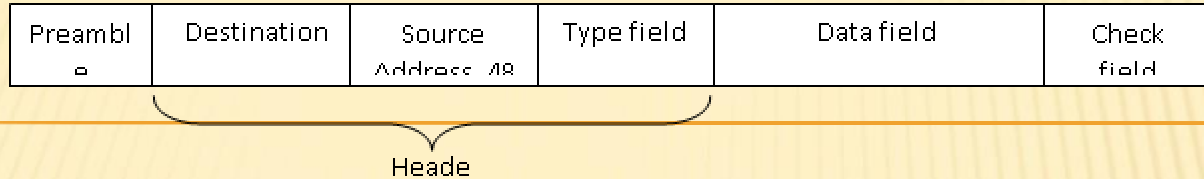
- At low values ρ<0.2, R-ALOHA pays the price of greater delay due to the greater overhead.
- For $\rho > 0.2$, collisions and retransmission of S-ALOHA cause a more quick delay increase.
- At higher throughput (ideal case 0.37 for S-ALOHA and 0.67 for R-ALOHA) the delay is unbounded.

Local Area Network

CARRIER-SENSE MULTIPLE ACCESS NETWORKS (ETHERNET)

- Ethernet is a LAN access scheme developed by the Xerox Corporation.
- Based on assumption that each local machine can sense the state of a common broadcast channel before attempting to use it.
- The technique is known as carrier-sense multiple access with collision detection (CSMA/CD).

Carrier-Sense Multiple Access Networks (Format)



- **Preamble** contains a 64-bit synchronization pattern of alternating 1's and 0's ending with two consecutive ones (i.e., 1,0,1,0,1,0,1,0,…,1,0,1,0,1,0,1,1).
- **Header:**
  - Receiving station examines a **destination address** field in the header to see if it should accept a particular packet.
  - **Source address** is the address of the transmitting machine.
  - **Type field** determines how the data field is to be interpreted (e.g., data encoding, encryption, message priority, and so).
- **Data field** is an integer number of bytes from a minimum of 46 to a maximum of 1500.
  - **Maximum packet size is 1526 byte (where a byte is 8 bits) as:**
    - 8-byte preamble
    - 14-byte header
    - 1500-byte data
    - 4-byte parity
  - **Minimum packet size is 72 bytes consisting of:**
    - 8-byte preamble
    - 14-byte header
    - 46-byte data
    - 4-byte parity
  - **Minimum spacing between packets is 9.6 μs.**
- **Parity check** field is added for error detection.

10 Mbps data stream with Manchester PCM

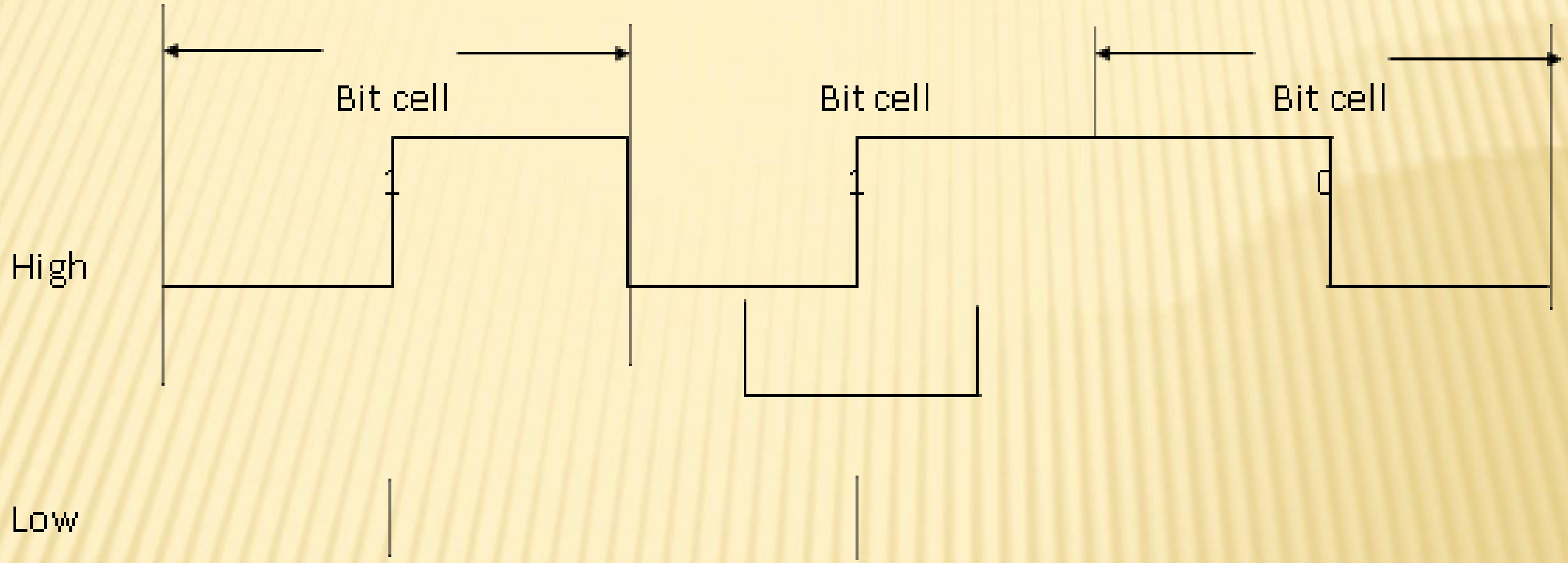


Fig.3.13 Ethernet Manchester PCM Format

- Each bit position contains a transition.
- Presence of data transitions denotes to all listeners that carrier is present.
- If transition is not seen between 0.75 and 1.25 bit times since last transition,
  - Carrier has been lost, indicating the end of a packet.

CSMA/CD, USER ACTION OR RESPONSE

- Defer: User must not transmit when carrier is present or within the minimum packet spacing time.
- Transmit: User may transmit if not deferring (when carrier is not present) until the end of packet or if a collision is detected. If a transition is not seen between 0.75 and 1.25 bit times since the last transition, the carrier has been lost, indicating the end of a packet.
- Abort: If collision is detected, user terminates packet transmission and transmits a short jamming signal to ensure that all collision participants are aware of the collision.
- Retransmit: User must wait a random delay before retransmission.
- Backoff: Delay before the ^{n}th attempt is a uniformly distributed random number from 0 to 2^{n}-1 for $0 < n < 10$ of the unit-time equivalent to 512 bits (51.2 μs).

Token-Ring Networks

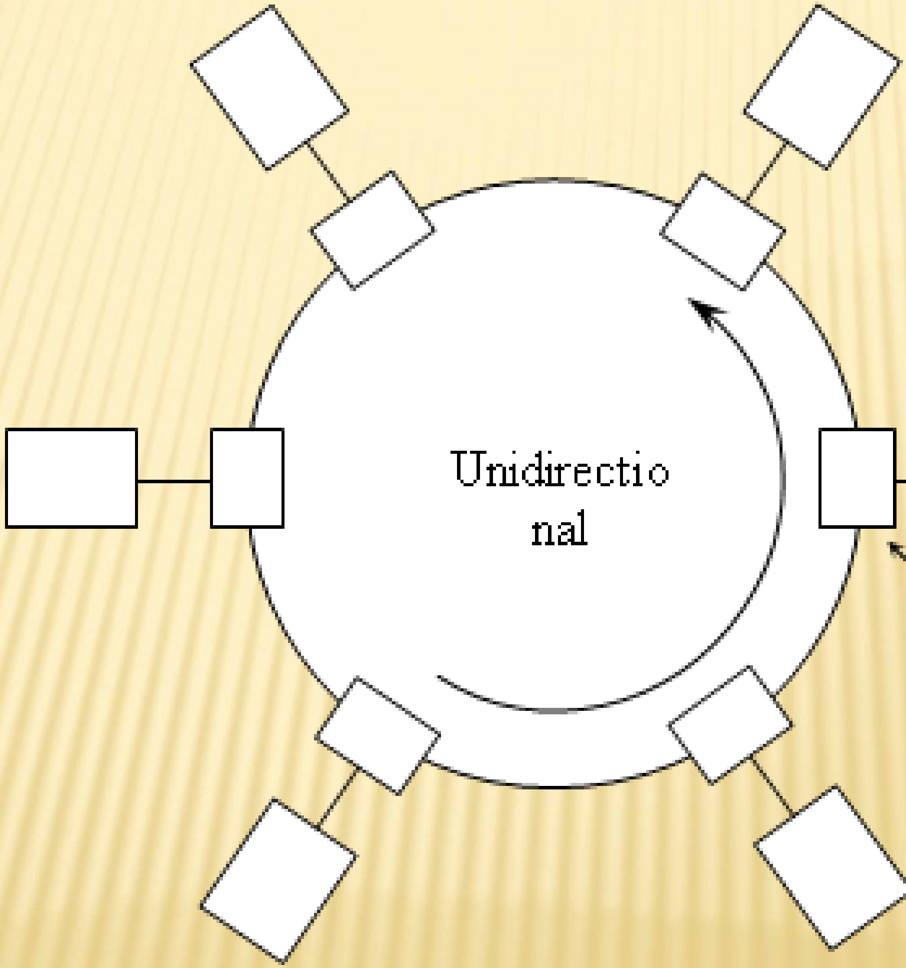


Fig.3.14 Token-ring Network

Comparison Between Token Ring and CSMA/CD

- CSMA/CD is a cable onto which all stations are passively connected.
- Ring consists of a series of point-to-point cables between consecutive stations.
- Interfaces between the ring and stations are active rather than passive.

Interface Modes

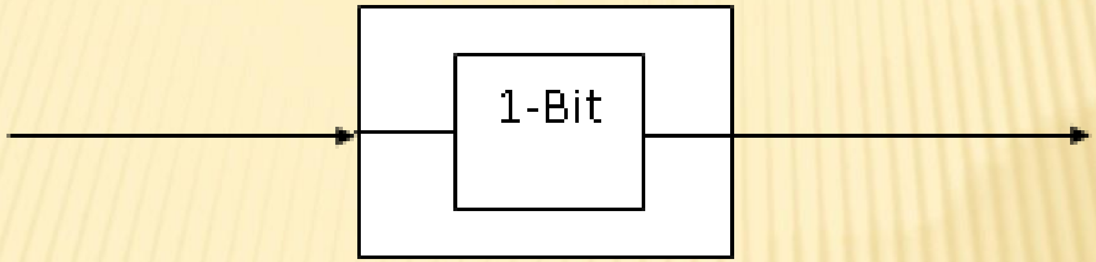
- **Listen mode:**

Input bits are copied to the output with a delay of one bit time.

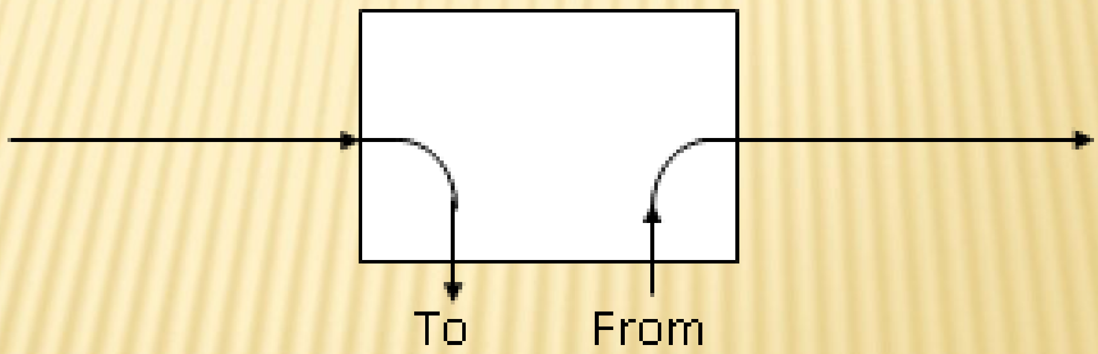
- **Transmit mode:**

The connection is broken so that the station can enter its own data onto the ring.

LISTEN AND TRANSMIT MODES



(a) Interface listen mode



(b) Interface transmit

Fig.3.15 Listen and Transmit Modes

The Token

- Token is defined as a special bit pattern.
- For example:
  - 8-bit token is: 1 1 1 1 1 1 1 1
  - It circulates on the ring when all stations are idle

Bit Stuffing

- Used to prevent the token pattern from occurring in the data.
- **Bit stuffing algorithm:**
  - Insert zero into data stream after each sequence of seven ones.
  - Receiver would use a similar algorithm to ignore it

Token Ring Operation

- Station monitors token appearing at interface.
- When the last bit of the taken appears, the station invert it (e.g., 1 1 1 1 1 1 1 0).
- Station then breaks the interface connection and enters its own data onto the ring.
  - ✓ There is no limit on the size of the packets.
  - ✓ As bits come back around the ring, they are removed by the sender.
- After transmitting the last bit of message, the station must regenerate the token.
  - ✓ After last data bit has circled the ring and has been removed, the interface is switched back to listen mode.

Contention

- Contention is not possible with a Token-ring system since there is only one token.
- During heavy traffic, the next station requiring service will see the token and remove it.
- Thereby, the permission to transmit rotates smoothly around the ring without contention.

Propagation Length

A major design parameter in ring network is the propagation length of a bit.

- **If the data rate is *R* Mbps,**
- **A bit is emitted every 1/*R* μs.**

Since the propagation rate along a typical coaxial cable is 200 meter / μs,

- **Each bit occupies 200/*R* meters on the ring.**

Example

If an 8-bit token is to be used on a 5 Mbps token-ring network, calculate minimum propagation distance d_P needed for the ring circumference. Assume that the propagation velocity v_P is 200 meter/microsecond.

Answer

Time to emit one bit is given by:

$$t_P = \frac{1}{R} = \frac{1}{5x10^{-6}} \quad \sec$$

Time to emit one 8-bit Token ring:

$$t_P = \frac{8}{5x10^{-6}} \quad \sec$$

Propagation distance of Token ring:

$$d_P = t_P \cdot v_P = \frac{8}{5} \mu \sec x 200 \; meter / \mu \sec = 320 \quad meters$$

CSMA/CD & TOKEN-RING COMPARISON

Delay-throughput characteristics of a CSMA/CD and token-ring. The comparison is made for

- 50 stations,
- 1000 bits average packets,
- 2km cable length, and
- The header length is 24 bits.

Delay-throughput Characteristics